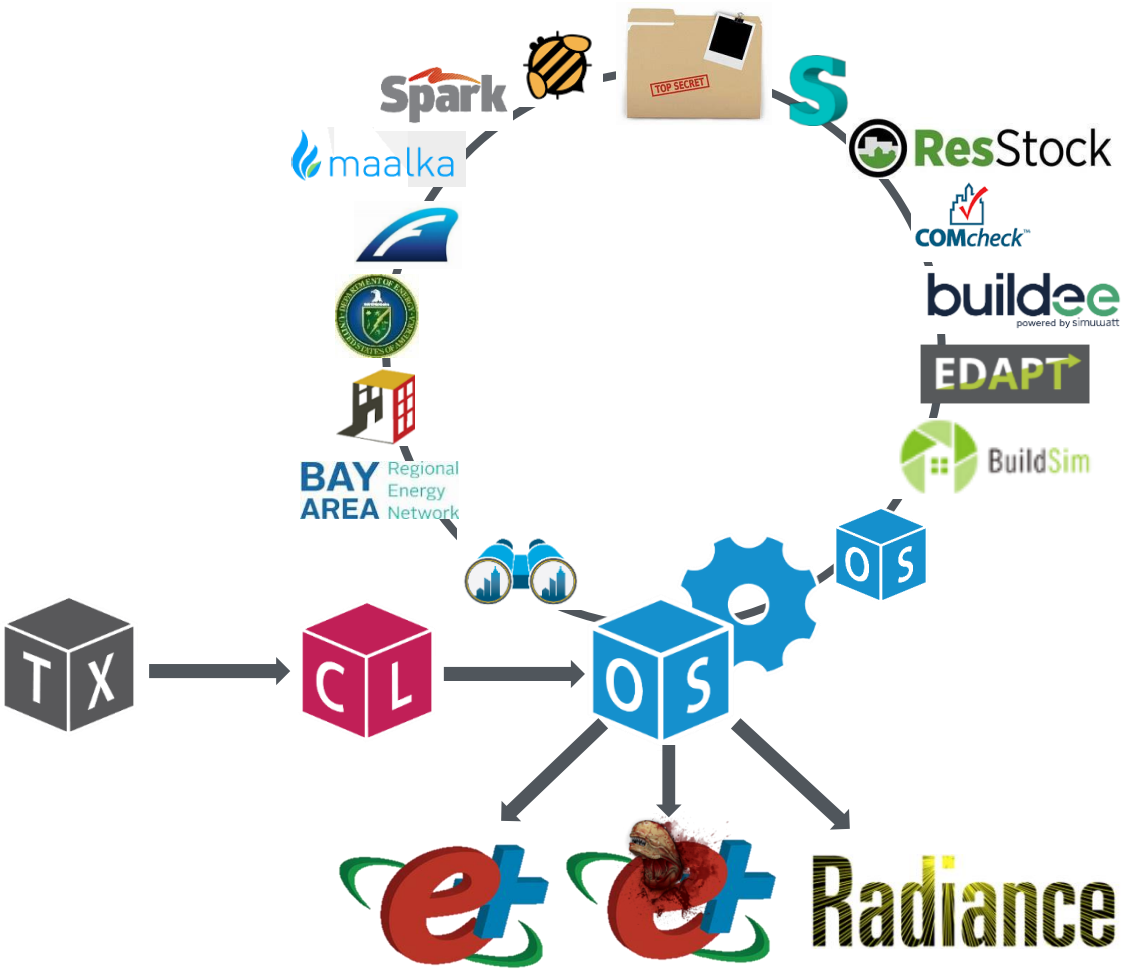
BTO Building Energy Modeling Sub-Program Review

http://energy.gov/eere/buildings/building-energy-modeling/

Apr. 16, 2019



U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Amir Roth, Ph.D.
amir.roth@ee.doe.gov

Today's Agenda

Part I: BEM sub-program review

- 40 minute presentation
- 40 minute Q&A

Part II: BEM roadmap (R&D opportunities document) discussion

- Six 20 minute vignettes organized around roadmap themes
- Three minute presentation followed by discussion
- May flex to spend more time on "larger" topics, e.g., workflow automation

BEM is a Cost-Effective ECM

Project Name	% Modeling Fees vs Gross Fees	Annual Modeled Energy Cost Savings	Payback on Modeling Fees in MONTHS
Office Building	0.7%	$122,876	2
Office Building	0.5%	$306,692	1
Justice Center	0.8%	$350,000	3
Convention Hotel	0.6%	$233,791	1
Regional Hospital	2.4%	$3,300,000	1
Government Office Building	3.3%	$186,000	4
Government Building 20	1.1%	$224,276	2
Cancer & Critical Care Tower	0.6%	$853,013	3
Institutional Research Center	0.6%	$340,000	3
Energy Institute	2.5%	$169,432	7
Institutional Research Facility	1.0%	$302,169	1
Science Teaching and Research Facility	0.8%	$419,599	1
Corporate Headquarters	1.0%	$239,835	4

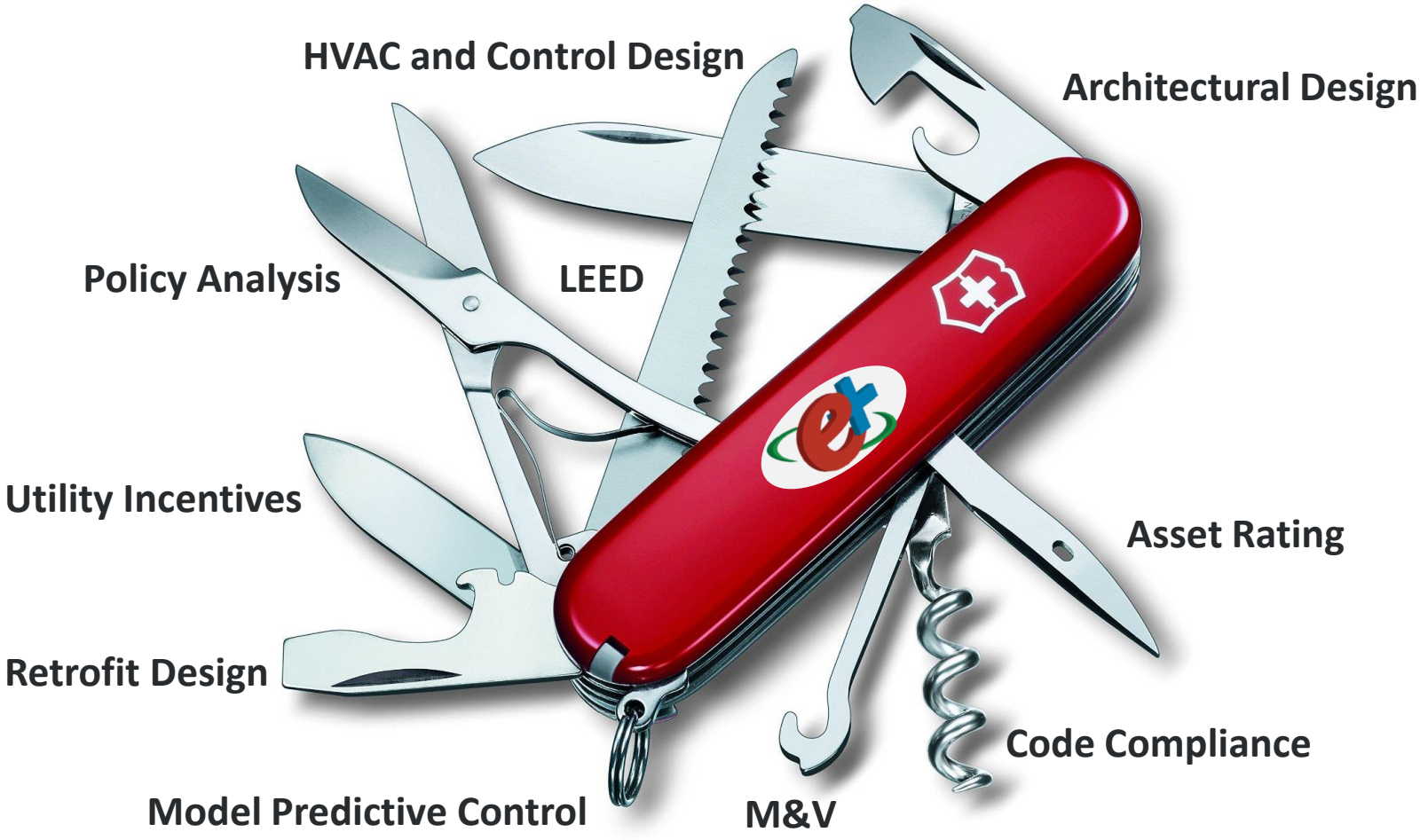
Source: HOK

BEM in integrated design

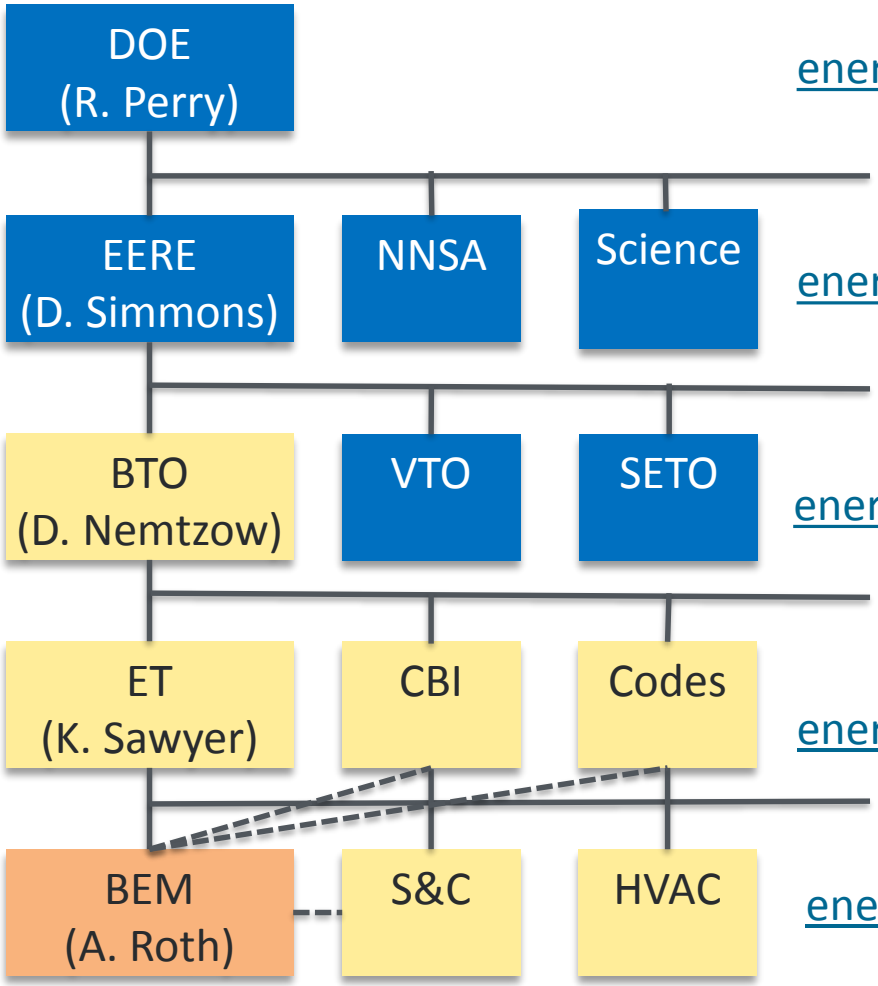
- Potential to save 0.7 quad/year by 2030
- Payback << 1 year & sometimes instantaenous
- https://energy.gov/eere/buildings/articles/shockingly-short-payback-energy-modeling

Codified in ASHRAE Standard 209

And a Lot More



What Is BTO's BEM Sub-Program?



energy.gov/

energy.gov/eere/

energy.gov/eere/buildings/

energy.gov/eere/buildings/emerging-technologies/

energy.gov/eere/buildings/building-energy-modeling/

An R&D area since the ERDA days

MC Amir

At this position since Sep. 2010

- Know what I'm doing since 2012 (2013? 2016? 2020?)
- Not a trained modeler or mechanical engineer → no excuse!
- Member of ASHRAE, IBPSA-USA, ACM, IEEE

Prior experience

- Asst. → Assoc. Prof. of Computer Science at Upenn (2001-2010)
- Brief stint at Intel Microprocessor Research Lab (2000)
- Software developer at Microsoft (1994-1995)

Education

- Ph.D. in Computer Science from UW-Madison (2001)
- B.S. in Physics from Yale (1994)
- P.G.S.S. (1989)

1, 2, 3 WE ALL WE GOT!

BEM Sub-Program Review

Sub-Program Evaluation

Traditional project-level review

- Merit Review – prospective
- Peer Review – retrospective

Trying something new … sub-program-level evaluation

- Complement traditional project-level evaluation
- Answer questions that are larger than individual projects (e.g., scope, whitespace)
- Evaluate DOE processes & execution
- Both backward & forward looking

New three year cycle?

- Sub-program review → Project Peer Review → Project Merit Review →

Sub-Program Evaluation Rubric

Scope (30%)

- Are barriers real, significant, and "appropriate"? Does sub-program address barriers?

Impact (30%)

- Does sub-program advance state of the art? Support industry?
- Does sub-program contribute to BTO's energy saving goals?

Collaboration, coordination & integration (20%)

- Is sub-program well integrated within ET, BTO, EERE, DOE?
- Is sub-program aligned & coordinated with relevant public and private sector orgs?

Communications & stakeholder engagement (20%)

- Does sub-program integrate input from proper set of stakeholders?
- Does sub-program provide sufficient, relevant, and timely information?

Metrics (10%)

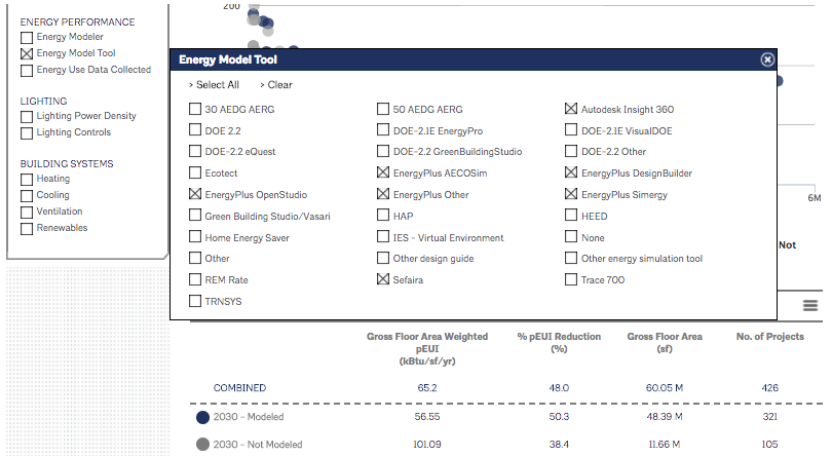
- Are metrics appropriate? Does sub-program perform well on its own metrics?

For each criterion: 1 (poor) – 4 (excellent) score & comments

Sub-Program Mission & Goals

Mission: Increase effective use of BEM in all aspects of building energy efficiency.

AIA 2030 Design Data Exchange



2020 goals ← 2014 (2016) MYPP

- BEM for new construction GSF: 70% (now: 47%*)
- EnergyPlus for new construction GSF: 5% (7%**)
- Savings over code: EnergyPlus: 20% (21%***)
- 3rd-party EnergyPlus applications & services: 12 (12)

Useful goals need data ← AIA 2030 Commitment (https://2030ddx.aia.org/)

- *Going down ← 2030 is growing “from the bottom”
- ** Going up ← Sefaira
- ***Going down ← codes becoming more stringent

Want additional goals (especially for other use cases) but data is hard to come by!

Logic Model

Sub-Program Outputs	Market Outcomes	Uber Outcome
SOTA capabilities: EnergyPlus, Spawn, Radiance	Improved developer & user productivity	Industry & market are confident in BEM & regularly use it to design & operate energy efficient buildings
Automation & productivity: OpenStudio	3rd-party apps & services	
Applications & Services: FOAs, SBIR	More professionals	
Resources & partnerships: IBPSA, ASHRAE, AIA	More consistent, higher-quality deliverables	
Accuracy & Uncertainty: ASHRAE 140, Validation	Increased confidence	
	Increased adoption	

EE evaluation capabilities **x** Applications & services **x** Professionals & productivity **x** Awareness & confidence **=** % GSF designed and/or operated

Also from MYPP

Activities (roughly) map to contributing factors

BEM Sub-Program Structure

Core projects

- Long-running, (multi) lab, mostly software development
- Merit Reviewed on a 3-year basis (FY19-21 cycle)
- Were here in 2016, will be here in 2022

Competitive projects

- Short, 1-3 year projects solicited through a variety of channels
- A few had started in 2016, whole new batch in 2022
- Tie-ins to existing software projects to avoid proliferation & fragmentation

http://energy.gov/eere/buildings/building-energy-modeling-project-portfolio/

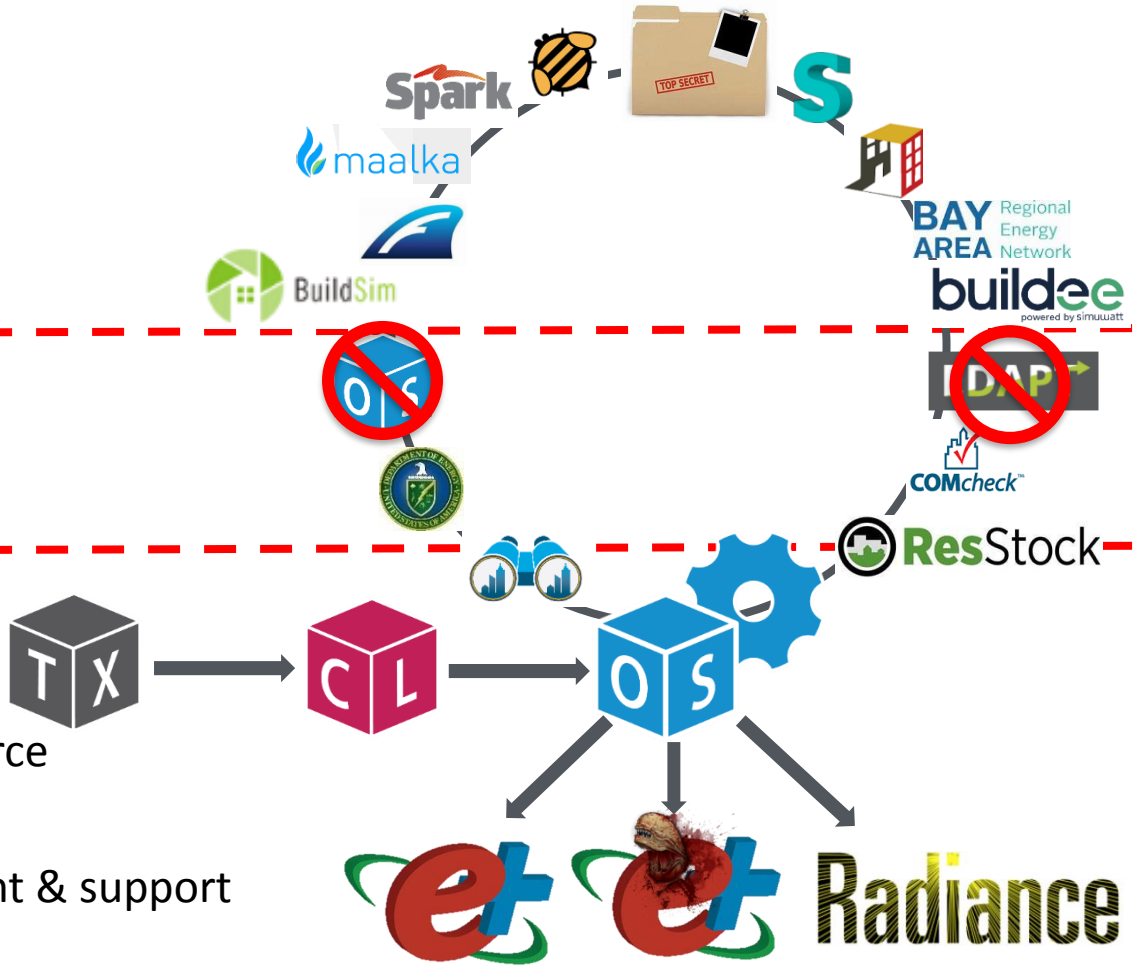
Sponsorships

- IBPSA-USA SimBuild, BuildingSim & biannual meetings, ASHRAE BPAC, SimAUD
- Ad hoc competitions

Support for other BTO & DOE internal projects

- Asset Score, Home Energy Score, Scout, ASHRAE 90.1 analysis

Software Philosophy & "Constitution"



Applications

- Prune
- Be selective going forward!

Platforms

- Serve vendors, not end users
- Commercial-friendly open-source
- State-of-the-art capabilities
- Commercial-grade development & support
- Long-term commitment
- Transparency & impartiality matter → public funding

Core Projects

Limited to labs designated "core" or "enabling" in BEM technology area

- Berkeley, NREL, Oak Ridge, Pacific Northwest, Argonne

Software

- EnergyPlus, OpenStudio, Spawn, Radiance, Windows Tools, ResStock, Scout

Others

- ASHRAE technical assistance (140, 205)
- AIA technical assistance (2030 DDx)

About $9,000k in FY19 (more than $8,000k on software)

- Highest since 2010, lowest was $4,000k (some double-counting with CBI, RBI, S&C)

EnergyPlus™ — Inputs

Meta-Data

- NREL (lead), LBNL, ORNL & a raft of sub-contractors
- $2,900k / year

Three year emphasis

- Test coverage & automation, bug fixing
- Use of standard libraries
- JSON (JavaScript Object Notation) input & output
- Object-orientation, refactoring & APIs (moving from “C++” to C++ since 2012)
- Residential modeling
- Multi-building, environmental & urban-scale modeling
- Control modeling & workflows, including Spawn
- Performance improvement

EnergyPlus 10X

- Three-year (FY19-21) sidecar, speed up EnergyPlus 10X using most available means

EnergyPlus™ — Outputs

umi

QCoefficient

jEPlus

eppy

Architecture, Systems

Insight

DesignBuilder

Euclid, Modelkit

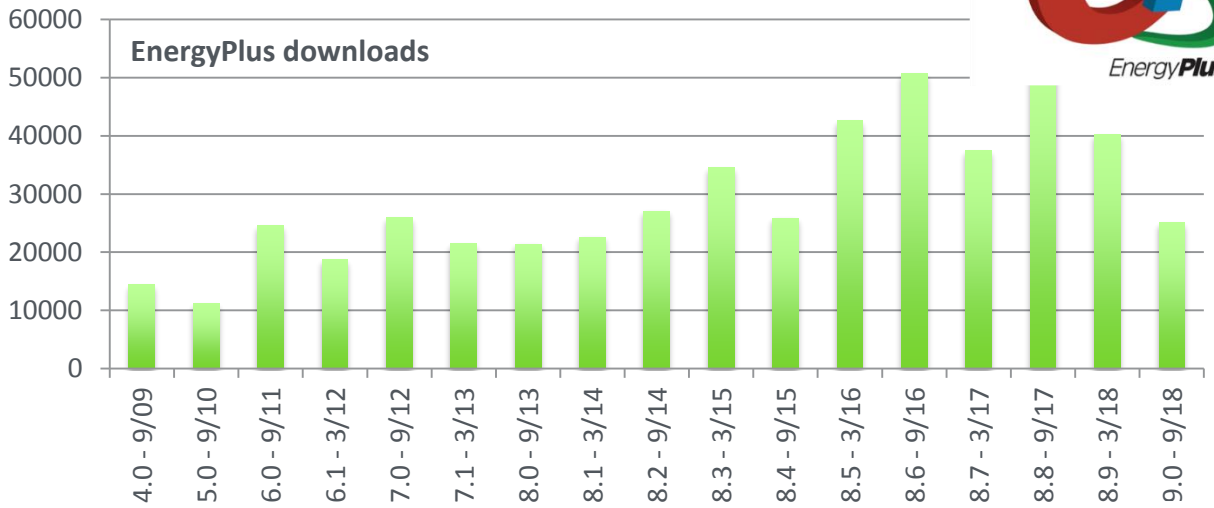
AECOSim

Simergy

TRACE 3D Plus

CityBES, CBES, COMFEN

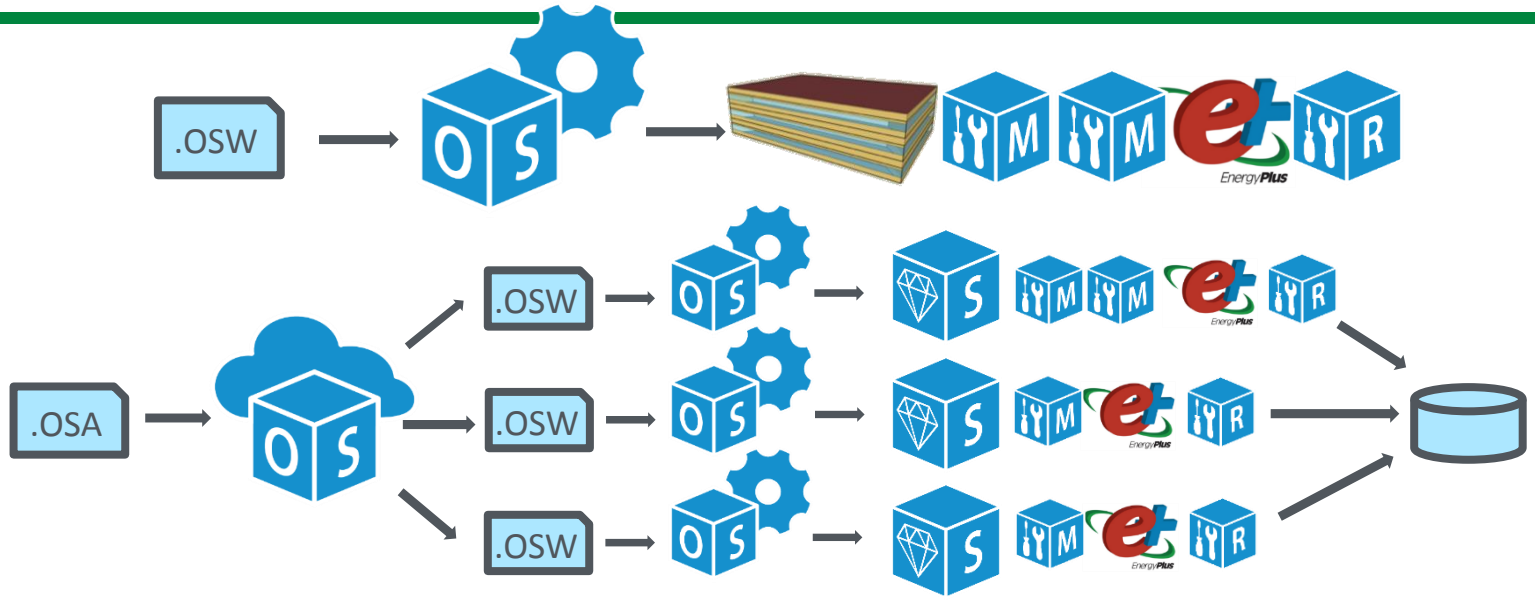
EnergyPlus



Doesn't include 3rd-party applications or services

Most widely used & cited engine in research publications ← open-source

OpenStudio 2.0



Three targets

- Application & service development
- Task & workflow automation
- Large-scale analysis ← major use-case for BTO itself

Three major pieces

- SDK & CLI (command line interface) – API for Applications & Measures
- Server – large-scale simulation on local machine, cluster, or cloud (Measures are key)
- Standards – prototype buildings & performance rating (Measures are key here too)

OpenStudio™ — Inputs

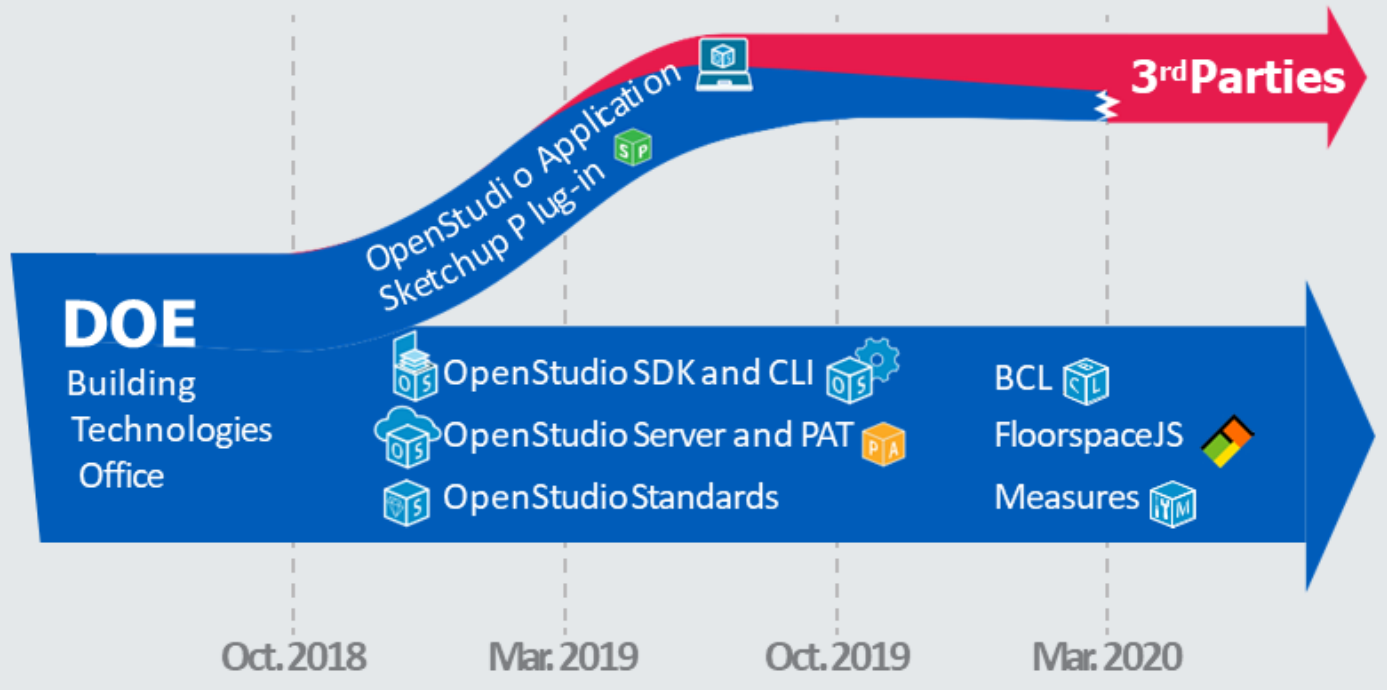
Project specs

- NREL (lead), LBNL, ORNL & PNNL
- $2,500k / year ← co-funding from CBI & RBI

Three year emphasis

- Test coverage & automation (include API & Measures), bug fixing
- Lockstep coverage of new EnergyPlus versions
- Improved coverage of EnergyPlus features
- Inter-operability – HPXML & BSXML (maybe others, e.g., CityGML, EnergyADE)
- Prototype buildings – offices with space plans, data center, grocery, CA
- Residential features
- Control, EMS & Spawn features
- Performance improvements
- Clean separation between SDK and graphical Application

“OpenStudio”™ — Ejecta



April 2020: graphical OpenStudio Application transitions out of DOE control

- Response to IBPSA-USA Vendor Advocacy Group … but was a matter of time anyway
- One (or more) third party will carry it forward, will remain open-source … or not
- OpenStudio SDK, Measures, Server, Standards gem, etc. are staying
- https://www.openstudio.net/new-future-for-openstudio-application

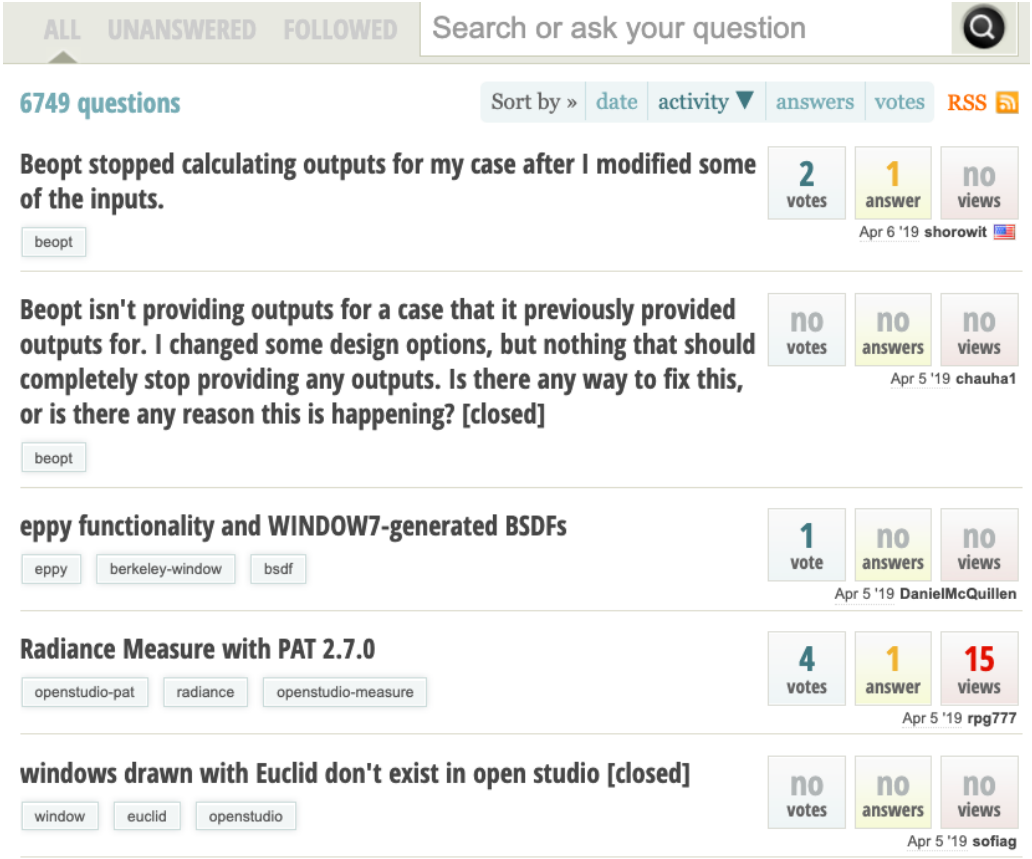
Clearest indication of impact!

Engaging User Community

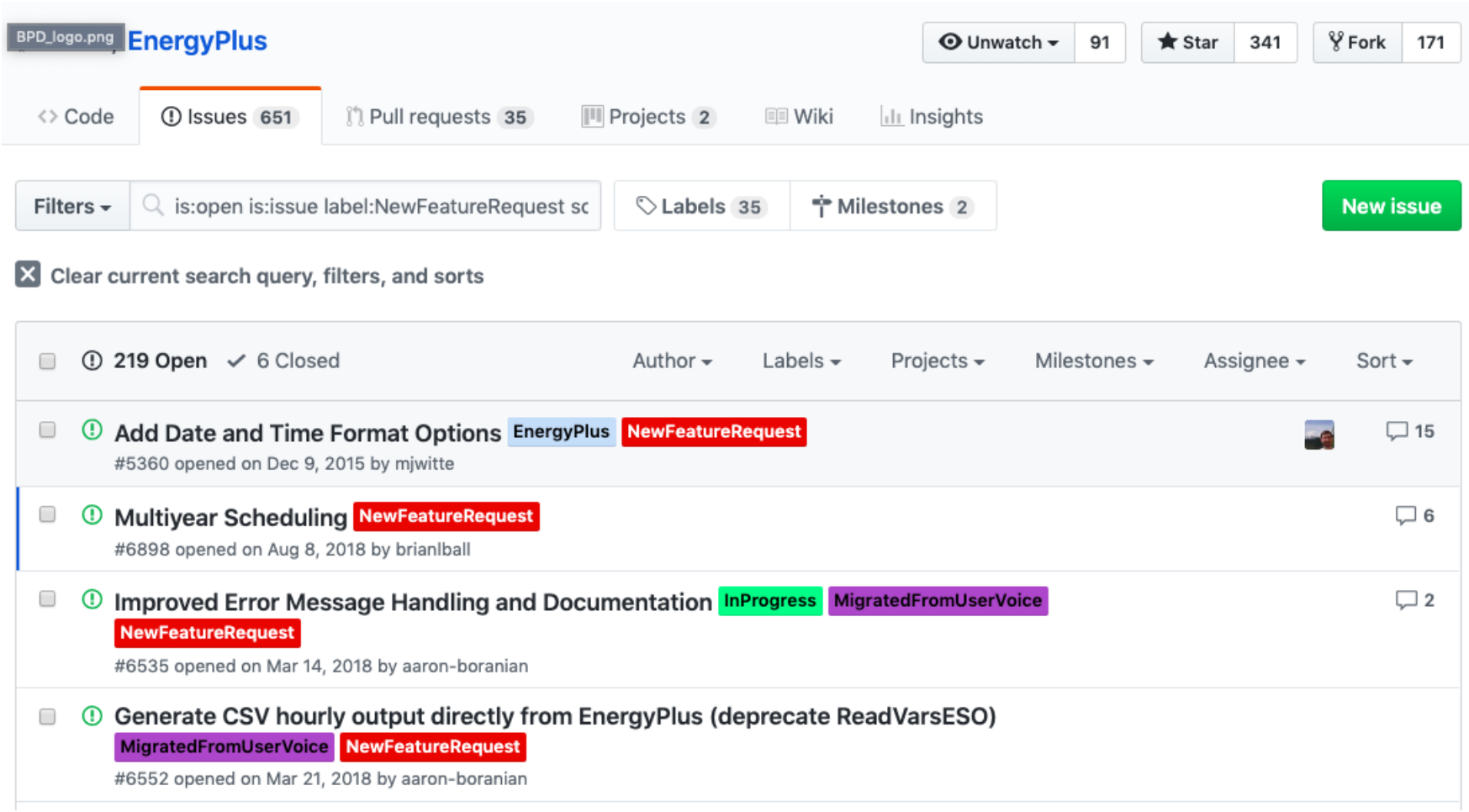
Third-party training only

Unmet Hours peer-to-peer help forum

- Many EnergyPlus & OpenStudio team members among top “helpers”
- 6,700+ questions in 4.5 years



Engaging User Community



GitHub Issues for feature suggestion, voting & tracking, bug reporting & tracking

(Known) third-party vendors sent annual feature request surveys

- These are plugged back into Github Issues

BEM-Control Nexus

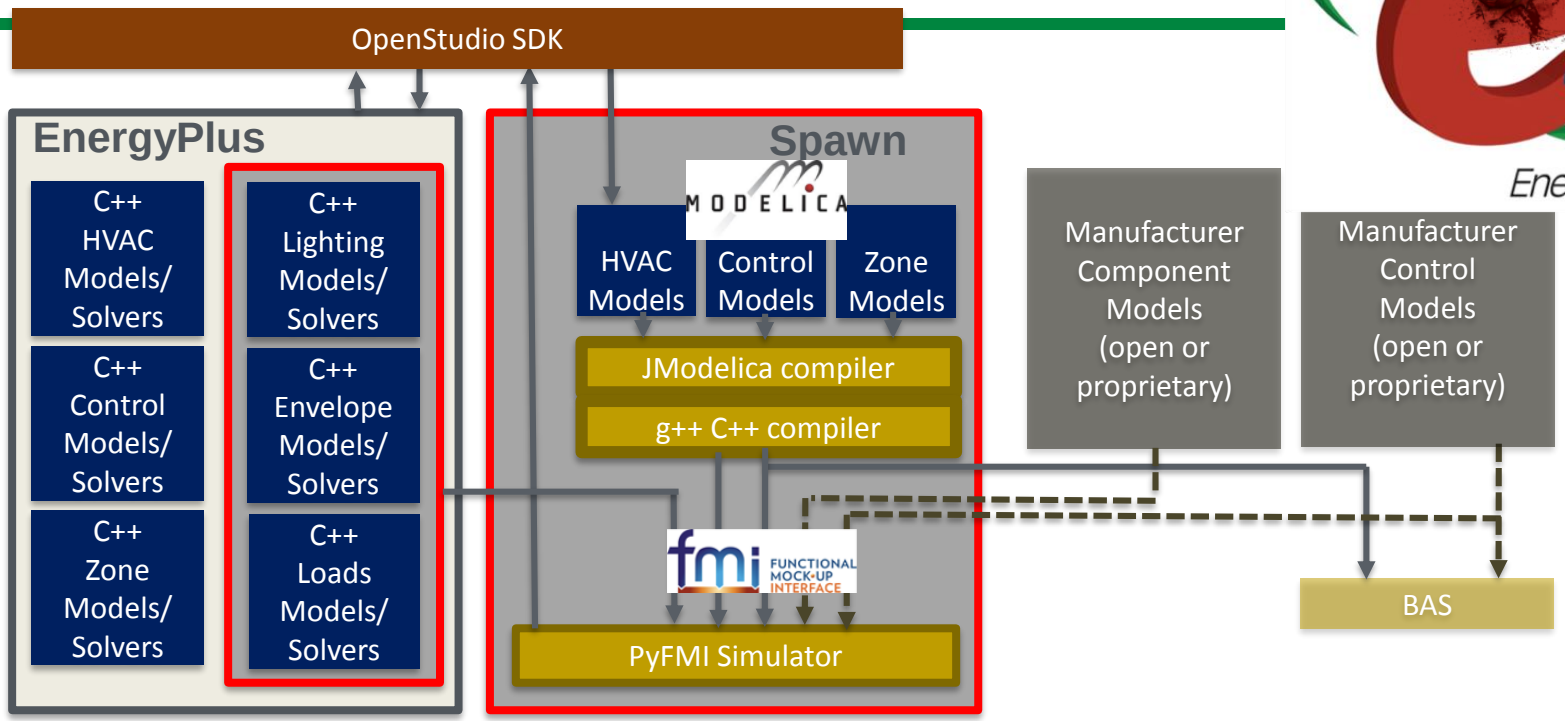
Recognize role of advanced controls in EE – bridge languages & workflows

- Cross-cutting portfolio → tomorrow AM

Support GEB (Grid-Interactive Efficient Buildings) vision

- Continuous integration of EE & grid services
- BEM, S&C, metering technology report → tomorrow PM

Spawn



Spawn (of EnergyPlus)

- LBNL, NREL, Modelon AB, IBPSA-USA Project 1 (formerly IEA Annex 60)
- $1,800k
- Re-implementation of HVAC & control using Modelica equation-based language
  - + Simulate physically realistic control & compile for direct execution
  - + Support 3rd-party component & control models, even proprietary ones
- Parallel to EnergyPlus for the foreseeable future, but eventual replacement

Competitive Projects

Lab call (lab must be prime) – 3 years, $1,500-3,000k

- URBANopt, EnergyPlus 10X, Empirical Validation & Uncertainty Quantification

BENEFIT (lab can be prime) – 3 years, $1,500-3,000k

- MOISTHERM (LBNL), Open Building Control (LBNL)
- Data Center Toolkit (CU-Boulder), Brick (UC-Berkeley), AirBEM (GaTech)

SBIR (small business) – 1 year, $150k

- Eight of these wrapping up right now

TCF (lab + commercialization partners) – 1 year, $150-750k

- One of these active right now

About $7,500k in FY19

Lab Call: Empirical Validation



Empirical data sets for ASHRAE Standard 140 (does not have any!) &

… unified framework for model & measurement uncertainty

- LBNL FLEXLAB, ORNL FRP & NREL indoor/outdoor iUnit
- 4 years (FY16-19), $4,400k

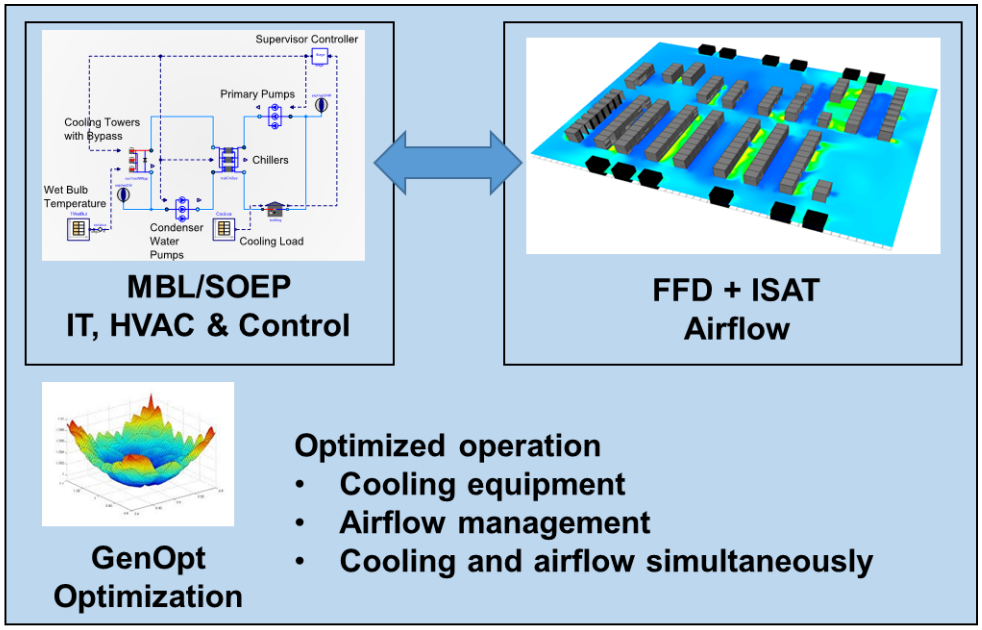
Goal: definitive statements about BEM algorithm/engine accuracy

- Increase practitioner & client confidence in BEM & specific engines
- Improve processes for handling uncertainty in BEM
- Move on to other things!

Results

- Data sets from 15+ separate experiments

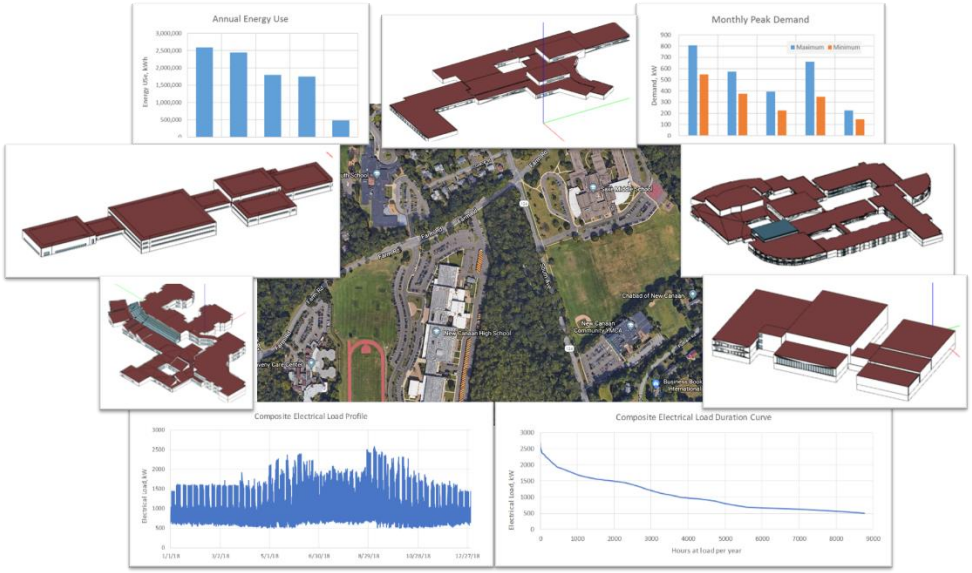
BENEFIT: Data Center Toolkit



Unified Cooling and Airflow Modeling and Optimization for Data Centers

- CU-Boulder, LBNL, Schneider Electric
- 3 years (FY17-19), $600k
- Modelica Buildings Library (cooling) + FFD (airflow) + genopt (optimization)
- 30% savings in datacenters in Cambridge, MA and Miami, FL

SBIR: Potpourri for $150k, Alex!



- Energy Analytics (Avon, CT) is developing OpenStudio Measures to help automate the analysis for energy performance contracting using microgrids.
- Prisere (Cranston, RI) performs risk analysis for the building insurance and re-insurance industries. Priesere is adding energy modeling to its workflow to allow these industries to more properly value EE and its resiliency benefits.
- Vistar Energy (Rocklin, CA) is developing a GIS-enabled BEM-based online workflow for residential EE upgrades. The workflow is being piloted by a utility in an EE program.
- Ladybug Tools (Fairfax, VA) is developing a Radiance-based online daylighting calculation service for architectural workflows.

Three Year Milestones & Successes

Internal milestones

- EnergyPlus features – JSON input/output, KIVA, CLI, data centers, residential, etc.
- OpenStudio 2.0 architecture
- OpenStudio Standards gem
- OpenStudio features – EMS, data centers, residential, ERI, etc.
- Spawn alpha
- Alfalfa (BOPTEST) alpha (5X) – generally BEM-SC portfolio (tomorrow)

External successes

- Autodesk adopts EnergyPlus as calculation engine in Insight
- Trane launches EnergyPlus-based TRACE 3D Plus
- RMI launches EnergyPlus-based Portfolio Energy Optimization (PEO) tool
- J2 Innovations launches EnergyPlus-based Finstack
- Legacy OpenStudio → Big Ladder Software Euclid
- New OpenStudio-based services Spark, BuildSimHub, Maalka

Major FY18 Success

Questions

Is BTO's open-source platform "magna carta" appropriate?

- It seems to be "working" … does that make it good?
- What should we be doing other than develop software?

Our major funding vehicles are lab oriented

What are we not doing or paying attention to that we should be?

ASHRAE, IBPSA, AIA, utilities … who else should we work with?

What do people need & want to know about the program?

- How do they want to consume this information?

How do we define & measure success?

- Metrics without data sets are like dining room tables with no chairs

BEM R&D Opportunities (AFKA Roadmap) Discussion

Background & Overview

First draft roadmap released in 2016

- Developed by Navigant Consulting (R. Zogg & E. Cross) – thanks!!
- Two workshops & several dozen phone interviews
- Tried to address BTO & industry as a whole
- 400+ comments received

This document subsumes 2016 document

- Developed by BTO (A. Roth with help from J. Reyna now at NREL)
- Attempts to address the initial round of comments
- Acknowledges industry, but focuses on BTO

RFI (request for information) out as of yesterday (?)

- Barriers – Real? Significant? Priorities?
- Initiatives – Likely to succeed? Appropriate for DOE to undertake? Priorities?
- Whitespace
- Original ideas
- Metrics, data sets, metrics, data sets, data sets, metrics, data sets & data-sets

Topic 1: Value Proposition

Barriers

- Clients invest when BEM is mandatory (e.g., code-compliance) or provides upfront value (e.g., a certificate). They decline to invest in design BEM because of skepticism of the value BEM provides over simpler engineering calculations & judgment.

Initiatives

- Develop and document compelling evidence that use of BEM for design & operation leads to robust energy savings. Document the costs associated with BEM.
- Develop and promote case studies highlighting the value of BEM.
- Leverage reporting programs to track use of BEM.

LEED created pull for less-than-useful post-design BEM

How to create pull for design BEM?

- "Increase electricity prices" is "correct" but not "helpful"

Topic 2: Predictive Accuracy

Barriers

- Clients “know” that BEM can generally predict energy use only within 30-50% but do not understand how much this materially impacts BEM applications. They consider energy use prediction as the fundamental capability of BEM & fail to see how, if it can’t do that, it can possibly be good for anything.

Initiatives

- Support empirical validation of BEM engines using well-characterized, well-instrumented test facilities.
- Support development & use of methods for model input calibration.

Is BEM one of the useful ones?

How do we move past this issue?

Topic 3: Core Capabilities

Barriers

- BEM tools are missing advanced capabilities in areas such as occupant behavior modeling, urban-scale modeling, and grid modeling.
- EnergyPlus execution speed is a hindrance in some applications, especially for residential buildings.

Initiatives

- Continue to improve EnergyPlus co-simulation support to leverage capabilities in other simulation engines.
- Develop a strategy for linking BTO's detailed envelope modeling tools, THERM, WINDOW, and Radiance with its BEM tools.

Have we maxed out EnergyPlus features?

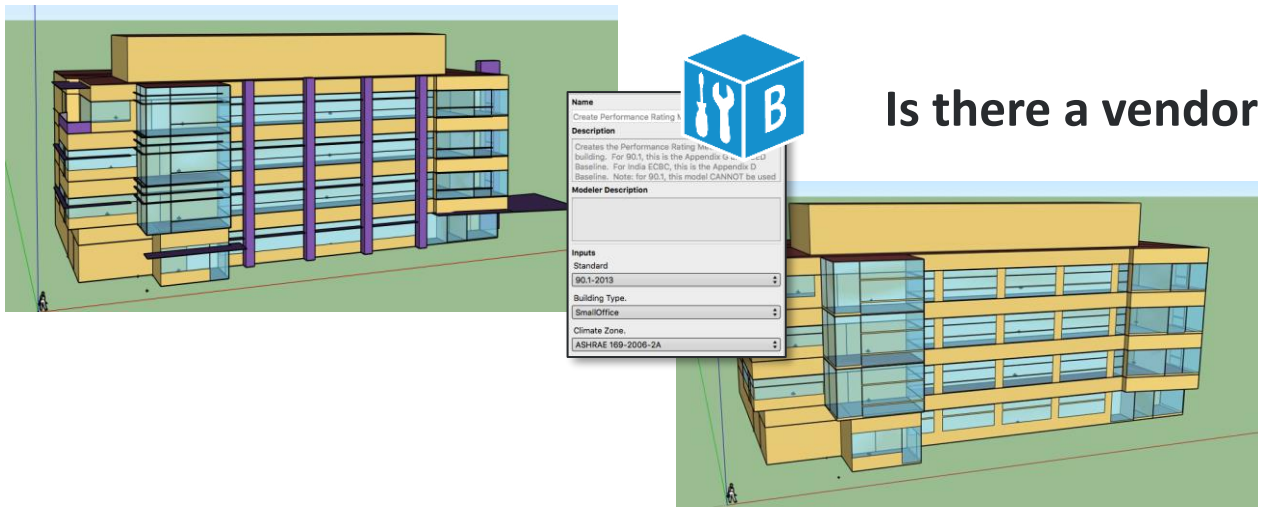
Topic 4: Workflow Automation

Barriers

- Mechanical modeling tasks such as generation of code-baseline model from a model of a proposed or existing building are not automated, degrading BEM value by introducing both effort and error.

Initiatives

- Work with design authoring tool vendors to improve consistency, robustness, and analyzability of design model exports.
- Promote use of OpenStudio Measures and other frameworks for task and workflow automation.
- Promote certification for automated BEM tasks such as baseline model generation.



Is there a vendor neutral BEM schema?

Topic 5: Supporting Data

Barriers

- Detailed equipment performance data used in simulation is outdated.
- EIA's RECS and CBECS do not have enough resolution and detail to support benchmarking for BEM use cases.
- TMY3 data does not represent the weather buildings will experience throughout their service lifetimes.

Initiatives

- Improve TPEX workflow to provide greater incentive for manufacturers to share performance data.
- Leverage BTO projects such as SEED, Asset Score, and Home Energy Score to complement CBECS and RECS.
- Expand the suite of prototype models.

Is TPEx an answer?

Topic 6: Education, Training, Certification & Standards

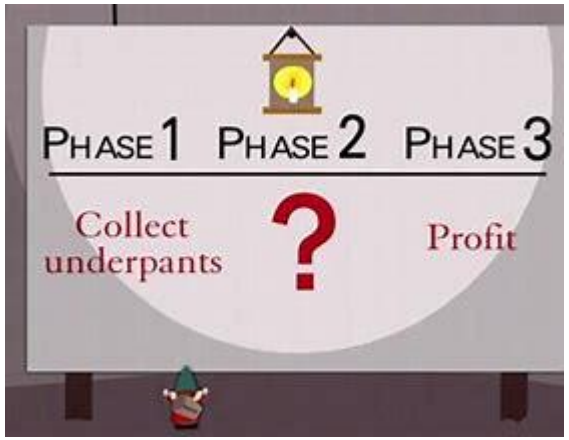
Barriers

- ASHRAE Standard 209 is not widely referenced or required. BEMP and BESA credentials are under-subscribed and not required by programs.
- Other than certification, there is no way to gauge modeler expertise, or even for modelers to gauge their own expertise.
- BEM curricula are sparse as are BEM training opportunities.

Initiatives

- Promote ASHRAE 209 and BEMP/BESA as requirements for GSA and DoD projects. Use AIA, Better Buildings, and utility alliances to promote 209 and BEM credentials.
- Use solicitations to support BEM faculty research & curriculum development.
- Leverage AIA 2030 Commitment to connect modeled data to measured data, helping modelers self-evaluate & market.

Where to begin?



Anything Else?

Thanks!

amir.roth@ee.doe.gov